When Space Heating Becomes Digitalized

Investigating Competencies for Controlling Smart Home Technology in the Energy-Efficient Home

Larsen, Simon Peter Aslak Kondrup; Gram-Hanssen, Kirsten

Published in:
Sustainability

DOI (link to publication from Publisher):
10.3390/su12156031

Publication date:
2020

Document Version
Publisher's PDF, also known as Version of record

sustainability

MDPI

Article

When Space Heating Becomes Digitalized: Investigating Competencies for Controlling Smart Home Technology in the Energy-Efficient Home

Simon Peter Aslak Kondrup Larsen * and Kirsten Gram-Hanssen

Department of the Built Environment, Aalborg University, A.C. Meyers Vænge 15, DK-2450 København SV, Denmark; kgh@build.aau.dk

* Correspondence: spl@build.aau.dk

Received: 17 April 2020; Accepted: 25 July 2020; Published: 27 July 2020

Abstract: In the near future, renewable energy sources (RES) will make up an increasing share of energy production in the district heating grid, implying that utilities must enable energy flexibility in order to compensate for the intermittent nature of RES. Current initiatives rely on smart approaches, encouraging a flexible energy demand by integrating various demand-side-management technologies. While praised for their 'smart' capabilities, smart home technologies have also been criticized for not meeting their potential in terms of savings and flexibility. This paper examines space-heating practices in everyday life in 16 Danish households. The study relies on qualitative in-depth interviews and 'show and tell' tours within these homes. Results show how space-heating practices are reconfigured by embodied knowledge related to respectively space-heating and use of smart technology. This implies that occupants' adaption to smart home technology is reconfigured by their previous experiences as well as the meanings they ascribed to their practices. By showing the different ways in which occupants 'get to know' smart home technology, results highlight forms of embodied knowledge which occupants habitually draw on when they heat their homes. Occupants learn and carry competences for conducting space heating throughout life, and interventions aimed at enabling a flexible energy demand need to consider this. As smart home technology is integrated in homes, interventions should consider embodied knowledge as part of occupants' competences for controlling smart home technology, as this will impact the reconfiguration of (new) space heating practices.

Keywords: smart home technologies; theories of practices; energy flexibility; competencies; everyday life

1. Introduction

Residential energy consumption represents one-third of final energy consumption in Denmark, and, with heating making up 84% of that share, it remains an important area of interest in the transition to a low-carbon future [1]. More than 60% of the Danish housing stock is supplied by the district heating network, making this system a key point of interest for the low-carbon transition. Furthermore, reaching the planned 100% renewable energy system in Denmark will require high integration of the electric grid and district heating network, allowing surplus electricity from renewable energy, primarily wind power, to be used in the district heating system, e.g., through large heat pumps. Thus, within both the electric grid and district heating system, flexibility in demand will become ever more important. Flexibility in short-term demand may imply both that peaks in demand are reduced or levelled out and that demand is moved to times when there is high renewable production from fluctuating sources, such as wind power. Several experiments and research studies have been done related to shifting demand within the electric grid [2,3], whereas flexibility in district heating is less developed and researched [4],

especially when utilizing an interdisciplinary approach. Technical energy modelling of buildings, however, shows that especially well insulated buildings with high thermal mass can be used to deliver flexibility to district heating systems [5,6]. These scenarios for flexibility imply preheating residential buildings and thereby avoid heating them during the critical morning peak (5 am–9 am), as well as the evening peak. This type of load-shifting is illustrated in Figure 1.

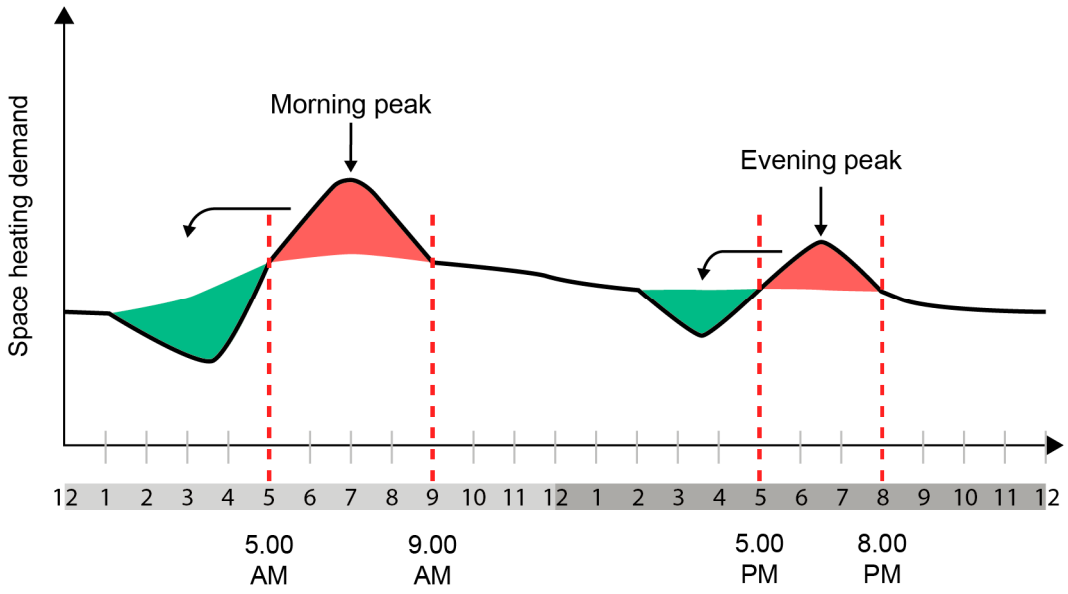

Figure 1. Illustration of load shifting.

One way to achieve load shifting in heating is through the use of smart home technologies, which can be controlled either by utilities or by occupants. These technologies allow demand to time-shift without occupants engaging directly on a daily basis by e.g., prescheduling space heating. Digitalization has for long been part of sustainable transition scenarios e.g., [7], and European countries have e.g., invested heavily in installing smart meters in households, especially within the electric grid, but also, to some extent, within the district heating net. Within the electricity sector, smart meters have supplied utilities with consumption data, allowing them to apply demand-side management, such as demand response (DR), where signals and incentives encourage occupants to modulate their electricity demands. Previous DR initiatives have often relied on economic incentives e.g., time-of-use-tariffs, feedback on consumption levels, neighbourhood comparisons or gamification, but the effects of these DR initiatives have been questioned in research [8].

Promoting smart home technologies as a solution to peak-demand issues in district heating can prove problematic if the perspectives of occupants are not considered thoroughly. Including perspectives on everyday life and the use of technology is important and implies examining space heating in a holistic manner, taking into consideration the norms, knowledge and technology involved in performing heating practices. This viewpoint is contrary to technological scenarios for the use of smart home technologies, where occupants are 'taken out of the equation' and replaced by increasing levels of automation [9–11]. In these scenarios, occupants are perceived as rational, able and competent agents, allowing an unproblematic adoption of these new technologies. If such assumptions about occupant behaviour are embedded within technology, then occupant engagement in real life circumstances can be problematic, as occupants might conduct workarounds in order to perform their space heating practices so that they correspond with their existing norms, knowledge and material arrangements already in place. Hence, competencies are of specific importance. Occupants perform heating practices based on previous (embodied) experiences i.e., what they have been exposed to throughout life. If occupant engagement with smart home technology does not correspond with designers' and engineers' visions, there is a risk that these technologies will not contribute to modulating the load. Therefore, the aim

of this paper is to examine how smart home technologies are used and understood by occupants in order to understand the potential for enabling energy flexibility in households heating demands by e.g., preheating households. Taking a stance in social practice theory, this paper examines the space heating practices which occupants perform and how they are reconfigured in the light of (new) smart home technology. Before delving into the empirical results, the next section summarises the current literature on space heating practices using a practice theoretical perspective.

2. Practice Theoretical Insights on Space Heating Practices

A growing body of literature applies a practice theoretical approach to space heating and everyday life [12–17]. These studies situate heating practices within a broader scope of everyday life. The practice theoretical perspective implies epistemologically that social practices are to be considered as the smallest analytical unit, meaning that every investigation of why and how people conduct space heating in the residential sphere must consider such activities as part of the set of social practices. According to some of the scholars who have advanced social practices theories [18–21], practices are constituted by a number of coordinated sayings and doings which are held together in a dynamic nexus of different elements. Scholars differ as to what these elements represent [22].

One element constituting a practice is referred to as practical understanding [23], understandings [20] or merely competence [19]. This element represents knowing how to perform a practice (both having the skill and being able to evaluate whether the performance of the practice is good). Competencies are something that people acquire when they are exposed to practices and perform such practices themselves [18]. Hence, competencies become embodied within the practitioner. The way people are performing e.g., space heating is thus a product of what they have been exposed to and what they have experience with. Furthermore, according to social practice theory, people are merely carriers of practices i.e., practices exist throughout time and space. Practices need to be re-enacted in order to 'recruit' new practitioners and cannot exist without being performed [18]. In terms of space heating, the way people perform space heating is a product of what they have been exposed to e.g., during childhood, including how their parents performed space heating. In a recent study, Hansen found that levels of energy consumption related to space heating and hot water are shaped by the accumulated experience of the practitioner [24]. In another study of heating practices, Rinkinen and Jalas [13] found that when occupants move into a new house, they exhibit variation in their performances with regards to their space heating practices, and, more importantly, they exhibit different routes for aligning with these practices. That is, occupants reconfigure space heating practices very differently, according to their existing practices and their embodied knowledge of how to conduct such practices. Facing new material arrangements for space heating is common when moving into a house (ibid.). Newly built houses will e.g., have better insulation, other heating sources and so forth. How occupants come to terms with such material arrangements will differ depending on their prior ways of doing things, including any embodied knowledge (ibid.).

These results also highlight how elements of a practice shape each other. Embodied knowledge concerning how to conduct space heating in a proper way is shaped by both the norms and values ascribed to the practice (e.g., economic incentives) and similar material arrangements in places (e.g., oil boiler) [25]. The relation between elements is dynamic, and, every time practices are enacted, reproduction is taking place, meaning that innovation in practices is dynamic (ibid.).

When integrating smart home technologies within households, a change in the material arrangement can occur. Smart home technology is also embedded with a specific kind of knowledge on how to use it properly and competently (through design practice). How this embedded knowledge is perceived by occupants is very much affected by their existing embodied knowledge and norms/values. However, embodied knowledge is also subject to change when there is a change in the material arrangement [16]. The relationships between elements are thus deeply interlinked and have constant interaction.

Smart home technologies for demand-side-management have also been touched upon in a practice theoretical context [26–30], but only a few studies have applied the practice theoretical framework to space heating and smart home technologies. The latter is the focus of this study i.e., to empirically investigate how space heating practices are reconfigured by smart home technologies. The focus is on the role of embodied knowledge and examining the importance of previous experience with ICT (Information and Communications Technology) and connected technologies, as well as space heating technologies.

3. Contributions

Research on energy demand flexibility has investigated the opportunities for load-shifting district heating demand [5,6]. These studies has mainly relied on technical modelling of the energy flexibility potential, and it is still unclear how occupants in real-life situations actually engage with demand-side-management equipment, integrated in their household. This study contributes to a growing part of the literature on energy consumption and everyday life, where social practices are the centre of analysis. By understanding how occupants perform everyday practices, such as space heating, it thus become clearer how to understand and possibly transform energy related practices. This is important as energy flexibility cannot be abstracted from social practices and doing so actually risk interlocking and stabilizing current practices [31]. By investigating everyday practices, which smart home technologies target, this paper presents important knowledge on how space heating practices are performed and how they reconfigure in very different ways, depending on occupants competencies. Apart from showing how heating practices reconfigure in varied ways, the contribution of this paper is also to show how heating practices are collective entities, which exists through time and space. Practice are carried by occupants, and only exist as they are reproduced in everyday life, through the performance of everyday practices.

4. Methodology

The research in this paper is based on qualitative methods. In the period from November 2018 to March 2019, in-depth interviews (in Danish) were conducted with the occupants of 16 Danish households. The key criteria for recruiting households were that households had: (a) district heating as their main heating source, and (b) some kind of connected technology allowing them to control and/or monitor their space heating consumption. For more detailed information on case selection, consult [11]. As the aim of the study was to examine occupants' everyday lives with smart home technology for energy flexibility, qualitative methods were preferred. The aim of the research was not to obtain external validity i.e., generalizable results of e.g., acceptance of smart home technology but instead to 'open up the black box' on how occupants engage with smart technology and why they do what they do. This aim included taking an inductive and holistic approach, thus taking into consideration not only direct engagement with the technology but also the wider aspects of everyday life that influence how space heating practices are performed.

4.1. Technology

The 16 recruited households were not equipped with identical smart home system setups. In addition to differences in technological setups, occupants also differed in terms of how long they had had the technology and their reasons for acquiring them. Three different smart home systems for space heating were included in this study. Key features of the systems are:

- Smart home setup A

This setup allows zonal control of heating from a central control unit. The central unit is Wi-Fi-connected, allowing wireless connection with all other devices (thermostats, smart phones, tablets, voice assistants and so on), and occupants can control devices away from home. The system also allows occupants to set up schedules for automated space heating.

- Smart home setup B

The second setup is a so-called integrated system connecting ventilation and space heating, allowing the two systems to work and react to each other. Furthermore, each room is equipped with thermostatic controllers, allowing zonal space heating control and providing additional (local) feedback to occupants on their indoor climate with regard to temperature, relative humidity and CO_2. Occupants can also control the system from their preferred devices (e.g., a smart phone).

- Smart home setup C

The third setup is more centralized. Smart units installed in the household switch between district heating and electricity for space heating—a so-called fuel shift solution. The smart unit reacts to signals from both smart meters and from production of energy sources (e.g., how much the wind is blowing). The home is also equipped with wall-mounted thermostats, allowing zonal space heating control. Using their computers, occupants can view daily consumption feedback from the utility.

4.2. Study Cases and Data Collection

The recruitment of informants took place within four case studies, all located in the greater Copenhagen area. Details of these cases are presented in Table 1. All four case studies represent residential areas where smart home technology was integrated for the control of space heating by utilities or other actors. Thus, households had not chosen to install the smart technology themselves. Within each case study, four interviews were conducted. The recruitment of informants sought to recruit households with different backgrounds in terms of age, household composition and educational/job background. Informants with different backgrounds were included in the sample in order to capture differences in how space heating practices are performed. Despite intentions to recruit occupants with different economic backgrounds, most occupants can be considered as being part of the upper-middle class due to the availability of residential buildings installed with smart technology. All four case studies involve low-energy buildings, and all but one case (case 1) are newly built. Table 1 contains further details on the four case studies.

Table 1. Details on study cases.

Case Number	Case 1	Case 2	Case 3	Case 4
Location	Roskilde, Denmark	Copenhagen, Denmark	Copenhagen, Denmark	Copenhagen, Denmark
Building type	Two-storey building	Terraced houses	Multi-storey building and terraced houses	Multi-storey building
Number of units	31 (both 1 and 2 bedrooms)	29 (100–200 m^2)	83 (45–210 m^2)	86 (55–146 m^2)
Year built	2004	2016	2017	2016
Space heating equipment	Radiators in rooms, floor heating in the bathroom	Floor heating in all rooms	Floor heating in all rooms	Floor heating in all rooms
Smart home technology	Smart home setup A	Smart home setup C	Smart home setup B	Smart home setup A
Ownership	Social housing for students. Rent is 500–800 euros per month	Ownership-prices start at 800,000 euros	Ownership-prices from 270,000 euros to over 1 million euros	Ownership-prices from 300,000 to 1.4 million euros
Residential characteristics	Mostly single students. Ages are 20–30	Mostly families with small kids, but also a few couples	Differentiated household composition—Mostly families with small kids and couples, but also a few students	Differentiated household composition—Mostly families with small kids and couples

4.3. Informants

Recruitment of informants occurred through gatekeepers, such as the chair of the housing association. These gatekeepers were also able to provide lists of occupants with the relevant contact information. Based on these lists, the final recruitment of households was made by phoning occupants and asking if they were willing to participate in an interview. In a few instances, occupants initiated contact and asked to be part of the study. All informants were informed about the research's purpose

and asked to provide consent (in accordance with EU law, The General Data Protection Regulation). Furthermore, informants were promised anonymity, and names are therefore pseudonymised. Table 2 contains details on the 16 households.

Table 2. Details on informants.

Household ID	Case no.	Main Informant(s) (Age)	Occupation	Household Size
1	1	Peter (21)	College student	1
2	1	Anne (25)	College student	1
3	1	Carina (25)	College student	2
4	2	Simon (51)	Civil engineer; Public official	2
5	1	Kirsten (23)	College student	1
6	4	Jan (45) and Carla (43)	Researcher; Physiotherapist	3
7	4	Noah (35)	Political adviser	3
8	4	Alexander (58)	Researcher	5
9	3	William (23) and Emma (21)	College students	2
10	3	Jacob (37)	Financial consultant	4
11	3	Charlotte (52) and Mia (45)	Consultant; Consultant	3
12	2	Benjamin (45)	Public official	5
13	2	Liam (58) and Olivia (55)	Politician; Consultant	3
14	2	Sophia (36) and Ethan (41)	Public official; CEO	4
15	4	Andrew (56)	CEO	1
16	4	Elizabeth (38)	Public official	4

4.4. Conducting Qualitative Interviews in the Domestic Sphere

All 16 interviews were conducted within the occupants' own homes and all but one (household ID 16) were conducted in Danish. The lengths of the interviews were $1\frac{1}{2}$–2 h and were semi-structured. An interview guide covering overall themes (everyday life, comfort, technology, energy consumption) and allowing follow-up questions or 'following a train of thought' presented by an informant was used. Space heating is often considered to be very 'invisible' by occupants i.e., occupants are not always explicitly aware of their space heating practices and the energy demand that follows. Hence, in order to capture which practices energy demand is being used for, it was deemed important to use an open approach and take into account other everyday practices [32]. The interviews also included a 'show and tell' tour of the occupant's house. The informants were asked to explain their use of the different rooms, including for which purpose they used them and why. This tour of the home also included observational studies on how the informants operated their smart home technology. During the tours, the informants were asked to simulate different routines (e.g., their morning routine). Out of the 16 interviews, nine were conducted with two interviewers present.

When there were two interviewers, one interviewer took the main role, while the other focused on taking notes and asking supplementing questions. All interviews were audio recorded.

Before each interview, an attempt was made to gather as many of the household residents as possible (including children) but, in some instances, doing so was not possible, and only one member of the household was present. These different household representations need to be taken into consideration, as there can be big differences in how different household members use and engage with the technology and which everyday practices they conduct, in general. Coding and the actual condensing of the data complexity was conducted in two steps. First, data was transcribed in order to make a thorough analysis. The data were then subjected to an abductive coding process using the software tool NVIVO. This process also consisted of two steps. First, an open coding process, in which the data were labelled according to what they expressed, was used, and then codes that were condensed into a closed coding list, thus limiting the number of codes, were used. Following this scheme allowed a more theoretically bounded analysis of the data when examining the patterns throughout the data. Quotes from the data were translated into English for this paper.

5. Results

The following section focuses on in-depth stories from four different households. Each ethnographic vignette provides a different approach towards engagement with smart home technology, showcasing how space heating competencies reconfigures space heating practices. The four vignettes put forward each represent a way of reconfiguring space heating practices that was found in other interviews. Thus, each vignette is representative of multiple households and represents an extract of different space heating practices in the smart home. Hence, the wide variation in how heating practices are reconfigured through the introduction of smart home technology is explored.

1. Carina—Young couple in student apartment

Carina is 25 years old and lives together with her partner Christian in case area 1. They are both in their mid-twenties. Carina is studying to become an engineer, while Christian is employed as a software engineer. This is their first time living away from their childhood homes, and they both like the cheap rent and close proximity to the university that their new apartment affords. Carina spends much of her weekdays at home, and she describes them as not being very routinized. During the university semester, Carina attends lectures two times a week, while study-group meetings are either held in the city or through an online platform. Carina and Christian are both very interested in computers and ICT equipment. They spend most weekends playing online or LAN (Local area Network) computer games until early in the morning.

In terms of the smart home system, Carina explained that they rely more on the automated features and do not make many day-to-day adjustments to the space heating system. Instead, she uses a feature of the smart home technology called scheduling, in which the system automatically regulates in accordance with a personalized setup e.g., allowing the temperature to automatically drop when they are asleep. The few adjustments they do make are primarily conducted during weekends, when they stay up late playing computer games and therefore want to avoid the scheduled temperature drop. Both Carina and Christian like to sleep in a cold bedroom, as they believe it makes them sleep better. When not sleeping, it is thought important that the bedroom be kept warm due to their computer playing activities, which require "warm fingers". In the living-room, the temperature is typically lower, as they put on a blanket while in there, which contributes to a cosy atmosphere, as the activities often involve watching TV. Carina and Christian's engagement with the smart home system is closely linked to ensuring a notion of comfort at home and the activities which unfold there. The notions of home and the notion of comfort are thus closely related, and comfort is perceived of as being more than physical wellbeing, as it also includes a mental notion of contributing to an atmosphere of security and care within the home.

When returning home earlier than expected, both Carina and Christian use the in-home display (IHD) to turn off the schedule. If the opposite is the case (being away from home, when the schedule is set to 'being at home'), they do not adjust the system as they "(. . .) *can't feel the difference*". Along these lines, Carina says that financial gains do not motivate them to make any adjustments to the space heating practices.

Carina and Christian apply different temperatures to the different rooms, at different times of the day. Normally, it is warmest in their bedroom during the daytime when they are not sleeping, but, as they use the bedroom for different activities, i.e., sleeping and playing computer games, the temperature is adjusted to the ongoing activity (e.g., warm when playing computer games and cold when sleeping). The living room and hallway are usually kept a bit colder than the other rooms. The temperature settings also vary across seasons. During winter, they like it a bit colder in their home, and, during summer, a bit warmer. According to Carina, they do this because they adapt to the outside temperatures.

They also air their home according to a special set of rules. They have two cats, so in order to get the "cat smell" out they prefer to air the apartment for 30 min each day by opening the doors on both ends of the apartment, ensuring a flow of air throughout. Carina explains that this airing practice

is something she learned in her childhood home. Carina's competencies provide a good example of how experience and exposure to practices are embodied and determine the way current practices are performed. Having the smart home system integrated into her home has altered her practices for airing, and she describes them as being more convenient and economically beneficial now. Carina adds:

> "*Before you had to just adjust all the radiators individually and it was very inconvenient, because they are tucked away behind desks and stuff. Now it is pretty easy to just come home and press 'you're not home' (ed. on the IHD) because when you're not at home, it's set to warm to 10 degrees or something (. . .) so you just put it on 'you're not home', conduct the airing and put it back to 'is at home' again.*"

In general, Carina finds that adjusting thermostats is inconvenient due to their decentralized positions (on the radiators). Previously, she therefore did not shut off the thermostats when airing but instead closed off some rooms. This has changed now.

Carina and Christian are very fond of their smart home system: "*I love it. If I could live in a fully automated smart home, then I would*", Carina states. Answering a question as to why she likes it, she adds:

> "*Well, I like the Internet of Things, the fact that you can just manage everything easily with an app or something. We both love technology, both me and my boyfriend and it's just cool. He is also a software engineer so he also know how to do programming. (. . .) We both have confidence in the technology. Many people think: oh, no and what if someone can control my space-heating and what if . . . We have a sensor in the bathroom, located in the shower, and it flashes blue light on me when I'm in the bath. If it wasn't because we actually trusted the technology then maybe I would too be a little apprehensive about having something hanging in the shower, but we're both just so totally relaxed around it.*"

Carina highlights their familiarity with technology as key. They both trust technology to a high degree. They are also not concerned about their data being abused by third-parties: "*If anyone wants to misuse one's data and such, then they can probably find more information on Facebook*", Carina adds. They are both used to controlling things with their smartphones, and they have many technological gadgets that they operate quite confidently. In terms of installing and setting up the smart home system, it was Christian who took charge. Christian also tinkers with the technology, e.g., setting up schedules in the app, while Carina mainly engages with the IHD. Being a software engineer, it is maybe not surprising that Christian is the main user of the technology, but that fact that he is the main user also highlights an interesting insight on how(and for whom) smart home technology is designed and what kind of knowledge is embedded within it. In the literature, Strengers [27] argues that smart home technologies are designed to conform to the so-called resource man. Christian fits that description in many ways, being a tech-savvy male who is used to managing quantifiable data and being more at ease when engaging with the technology. Christian and Carian's approach to learning how to use the smart home system is quite similar. It was a 'learning by doing' approach. They did not read the manual; instead, they downloaded the app for the phone and went from there. The initial setup was done rather quickly (1 h), and, after a couple of weeks, they found the "schedule" that they liked, as Carina explains:

> "*So, within the first hour, it was set up with what we thought we liked, and then within a week, it was set up with what we actually liked. What you think you like is another thing than what you actually like.*"

Their finding was that they actually liked it to be warmer than they thought they would, which came as a surprise to them.

2. Noah—Nuclear family with small kids

Noah (35), Sophie (33) and their son (5) live together in what is now their third apartment, in case area 4. They used to live in an old apartment, so moving into something newly built is a new

experience for them. They are generally very happy about their new apartment and location but also a bit disappointed in some of the building materials and building defects.

Noah describes everyday life as relatively structured. They wake up at the same time every morning and usually return late in the evening (taking turns picking up their son from kindergarten). Weekends include more leisure time, which is usually spent at home, although both Noah and Sophie's jobs demand that they sometimes work from home. Being the biggest room in their apartment, the combined kitchen and living room is the 'natural place to gather as a family', and they eat, cook and watch television there.

There is floor heating throughout the apartment, and, despite the comfort of having warm feet, Noah and Sophie are not very happy about the floor heating—it takes too long to regulate. Due to the slow response time of the floor heating, Noah does not turn off space heating when they are away from home for smaller periods of time, as he does not feel that it is worth it—both in terms of savings and loss of comfort. Instead, they have reconfigured their notions of comfort in order to achieve a 'hassle-free' and friction-less everyday life at the expense of adjusting the temperature on the thermostat. Noah explains:

> "*I think that we feel a little cooler here than we actually want to be. (. . .) If we lived in our old apartment with radiators, then we would adjust the temperature much more. In the old apartment, if we were coming home from a cold day, such as today, then we would turn up the heat. We don't do that here. If we are cold, then we put on a sweater, and inside our bedroom, for example, we can't get it cold enough, so we open up the window when going to sleep. And if I get too warm in the apartment, if I feel like I need to 'freshen up', then I'll go out on the balcony for a few minutes and get some fresh air and then back in. I think that's fine.*"

Noah describes these new conditions as affecting his comfort and something he just needs to accept:

> "*You can feel that it is a completely different temperature and indoor climate, compared to the old apartment, where you could just turn up the radiator and then it was nice, and you could almost lie in your underpants on the sofa a little after, if that's what you wanted. It's just not like this here. I just think you need to accept it.*"

Despite the difficulties in regulating the indoor temperature, Noah tries to maintain zonal control of the space heating, so that set points accommodate the activities taking place in the different areas of the house. They like their bedroom to be cold in order to get a good night's sleep, and the guestroom heat is almost turned off, as it is not used very often. Their son's room is a bit warmer than their own bedroom, as it is also used for playing with toys and so forth. Despite applying zonal control using the smart home system, Noah only feels little differences in temperature between the rooms. Noah has therefore tried a strategy of closing doors but cannot get it to work, as he feels that the doors are of bad quality (and there's a crack underneath allowing heat out).

Neither Noah nor Sophie have a technical educational background. When moving into their new apartment, one thing that appealed to them was that the apartment did not require much of them but was a 'plug and play', to use Noah's own words. From the start, Noah found the smart technology for space heating very interesting, and he approached it with an 'open-mind'. The first thing he did was to download the app to his smart phone. He enjoyed the feature of putting the system into 'holiday-mode' (turning down the heat when not at home). Asked about the reasons for doing so, he answered:

> "*Because there are climate considerations, but there is also a financial consideration, which I like. I did it (used the 'holiday mode') for the first 2–3 holidays and then, I have to admit that since then I haven't used it. I'm not using this app either. In fact, I don't even know if I can log in to it or if I forgot my password. But this is kind of where I am now.*"

So, despite initial interest in the smart home system, Noah's engagement with the system has been decreasing. Asked about the reasons for this decrease, he answered:

> "*We probably don't engage much with it because we forget it. When you had the radiators on the wall, you had a 'check-list', going around switching off the lights and checking the doors, emptying the refrigerator and turning down the radiators. And we haven't really incorporated a rule similar to that, and it's really stupid, because it takes two seconds to press it* (the IHD), *so it would be the easiest thing in the world, but we haven't. We just forgot about that. (. . .) But, again, it is also because when it is such a thing, it disappears a little. When you don't have the physical appliances hanging on the wall, then you do not feel it in the same way. There is some kind of satisfaction in going on holiday and when returning being able to feel that the apartment is cold, and it is such a good feeling knowing that "well yes, it has been cold the entire holiday (. . .)" But now, when we go on holiday and you don't see the radiators, you do not think about it (. . .) And you can't physically feel if they have been cold or warm. So when you have this system (current smart home system), you start to think how much does it really matter?*"

The above quote from Noah highlights an interesting insight into how people engage with smart home technologies, which rely less on direct human engagement and more on a 'plug and play' approach. As in the case of Noah, these 'plug and play technologies' actually lead to less meaningful engagement with the technology. The concept of 'onerous consumption' [33] might be useful in explaining why Noah intentionally engaged in more time-consuming practices (e.g., physically turning off wall radiators before a holiday) i.e., it gives him the benefit of engaging actively rather than using the passive 'set and forget' feature that the 'plug and play' technology prompts.

After the initial 6 months of use, Noah and Sophie did not engage very much with the system. Their set points are the same all day, every day, and they do not shut off or pause the smart system when airing. While Noah likes tinkering with new technology, he is not very impressed by the design and features of the smart home technology. For him, it is too complicated and lacks usability.

> "*It feels a bit like a 1st or 2nd generation software. The thing about having to push back and forth and you come across some things that you don't quite understand, makes me feel like I'm already 60 years old (laughs).*"

In general, Noah would like a smart home system that entailed less direct engagement and more automation. He thinks the current system is too complex and is not tailored enough to his everyday life, thus demanding too much attention and time from him. He would instead prefer more pre-installed settings, which, at the same time, are personalized to his apartment and everyday life:

> "*I get kind of tired when I feel I have spent a little energy on setting it up and it doesn't seem to work. Then I get a little tired. So sometimes when we talk, we wish we could just be back in the good old days, where it was a little more manual. So, technology is fantastic, but it should work.*"

3. Charlotte and Mia—Middle-aged expats

Charlotte is in her early 50's and has lived outside of Denmark for the last 20 years, and she still works outside Denmark. In 2016, she bought an apartment in Copenhagen (case area 3) and now spends every weekend there. The main reason for buying her current apartment in Denmark was that she could live here without moving her address permanently. Furthermore, she saw it as an investment. Charlotte is trained as an electrical engineer, but works primarily with IT in the financial sector.

In her apartment abroad, Charlotte controls space heat using manual thermostats. The good indoor climate in her new apartment is quite different from her place abroad, where the indoor climate is not quite as good. Her weekends in Copenhagen differ a lot from weekdays, which are structured by work. On the weekend, she typically wakes up later in the morning and spends more time in the kitchen cooking or on the balcony if the weather is good. During the week, Charlotte sublets the apartment to Mia, who works in Copenhagen during the week and is away on weekends. They know each other from working together abroad.

Charlotte does not adjust her space heating very often—once when arriving at the apartment (21 °C) at the start of the weekend and once when leaving the apartment (17 °C) at the end of the weekend. In between, Charlotte does not adjust it at all. While giving the home tour, Charlotte asked multiple times about the 'correct' settings of the thermostat and is generally concerned with practicing space heating in a manner that is economically feasible. Despite this, her new smart home system confuses her. Charlotte has experienced automatic changes in the set point that she has put in multiple times, and it is during the interview that she realizes that it is happening due to an automatic shut-down when the balcony door is opened.

Charlotte's way of airing her apartment is also quite routinized—she airs the apartment two times daily for ten minutes each—once in the morning and once in the evening. While airing, she does not shut the thermostats off, as she is unsure if the smart home system does so automatically. Charlotte's way of performing airing practices in her home makes it explicit that her competencies are related to previous and non-ICT related competencies. At the same time, the integration of smart home technology into her home challenges these competencies by e.g., not allowing her to shut off the thermostats while airing, which she previously used to do.

Another important element in determining how occupants perform space heating practices is their notion of comfort. In the case of Charlotte, but also others, comfort seems to play an important role—especially in the bathroom. This importance is also reflected in the literature, where notions of comfort are viewed as relating to both the body (and mind) and the material surroundings [17,34]. Comfort for Charlotte is an embodied sensory feeling of standing barefoot on warm tiles. It is important for Charlotte to keep a high temperature in the bathroom. She especially likes it when her feet get warm standing on the tiles. If Charlotte does not feel comfortable with the indoor temperature, her normal approach is to change her attire e.g., by putting on shoes. She does this instead of regulating the temperature. In general, Charlotte does not perceive of herself as a person who needs very high temperatures—her maximum is 23 degrees and then only in the bathroom.

While Charlotte has used just the IHD for the past year, she has recently downloaded the app allowing her to control the apartment as an integrated system i.e., the app will allow her to control both lights and the temperature. In general, she thinks of the app as a fun gadget and something to show off to her friends. The first time that she tried it, she went outside to a place where she could still see the apartment and operated the app from there. Charlotte is not very interested in using the app on a daily basis and has until now only used it to control lights: "*I do not know if you can also control the temperature. But it doesn't matter that much now. It's only a toy*".

When she moved into the apartment, Charlotte carried out a series of planned and systematic tests in order to learn how the smart home system worked. Such tests often involve items which Charlotte feels comfortable around and that she trusts. In the bathroom, she wanted to know if the displayed temperature was correct, so she brought an analog thermometer:

> "*In fact, I think I bought it (an analog thermometer) because of the problem with the heat control in the bathroom, which did not really work, so I thought, something is not right here, so I bought it to check what the temperature was really.*"

Another test involved checking which on-wall thermostats controlled which parts of the underfloor heating. She turned off all thermostats but one and set it to the highest possible temperature in order to feel where the heat came from. Charlotte's approach to learning about the smart system is usually to read manuals. If that does not give her the answers, she is quick to ask for help from technological developers or other intermediaries. Charlotte is interested in energy savings and for a while has been tracking her electricity consumption in a notebook. She also keeps all the internal doors in the apartment open, rationalizing that maintaining a stable temperature throughout the apartment will lower her utility bills. Hence, Charlotte is quite knowledgeable about energy consumption and how to conduct space heating to keep bills low.

However, in the light of her new smart home control options for space heating, Charlotte feels that things are a bit out of control—in her own words, she feels challenged. Charlotte feels that her competencies, acquired through many years of performing space heating, are not 'good enough' any more in in terms of performing the practice in a way she finds meaningful (achieving cost savings while maintaining comfort). Her main concern is that there are many new things to learn. Despite finding the smart home system less useful than a traditional system, she thinks that enabling energy flexibility and pre-heating the house during the night are interesting concepts, as they could be economically beneficial. She feels that it is very important that occupants give their permission for any external control and have the right to override the system.

Both Charlotte and Mia are concerned about the risks of being hacked or having their privacy compromised. As a result, they rarely give out any personal information. This concern extends to the smart home technology, with Charlotte stating:

> "*I am a bit doubtful of the app. Firstly, I do not think it is very user friendly and secondly . . . (. . .) The app is OK. It's pretty simple, but the system they have when logging in is not. It is difficult to operate, and you have two different passwords—one for the app and one for controlling the building, I don't think that works very well. I would prefer that they would send an SMS code to your private phone before controlling anything in the house. It is not like that, and therefore I thought, "Okay, it doesn't seem very safe". And that is a bit creepy. That if someone hacks it, then they can control my home and my space-heating and stuff like that. Therefore, I might would have wished for a little better security.*"

4. Simon—blended family with teenage kids

Simon (51) and Melissa (49) have been living in their new terraced house (case area 2) for three years. Simon and Melissa previously lived in the suburbs but wanted to move closer to the city to accommodate their kids in terms of being closer to school and friends. However, being in their late teens, their kids quickly found their own apartments in the city, and Simon and Melissa now live on their own. Simon is a civil engineer specializing in construction, and Melissa is a public official. Simon has lived in many places throughout his life, but he especially remembers the lack of insulation in his childhood home:

> "*We were sitting at our desks. You don't do that anymore. And we sat there in the winter, having icy feet because there wasn't much insulation in the floor. Then you put your feet up against the heater.*"

The memory of a cold childhood home has had a sensory effect on Simon and since that time he has thought a lot about space heating and how to keep warm. It was not until late in life that Simon experienced underfloor heating. It is something he really likes, thanks to the memories of cold feet in his childhood home. Simon describes himself as a DIY man, and, throughout his life, he has renovated and repaired different heating systems. He has done so in order to make his space heating more efficient—something that he used to be very concerned about. In their current house, Simon and Mellissa now have district heating, something Simon really likes: "*It's so nice. It's so hot. We never think about it*."

Simon and Melissa's house has three floors. Therefore, they only turn on the space heating on the bottom floor, allowing the heat to flow upwards. This usage reveals a specific form of space heating competencies which ensures comfort in an economically beneficial way without the use of ICT. Sometimes they also close off the rooms on the top floors if they want them to be cold. They control their space heating using the thermostats on the walls in the zonal areas, but, due to the design of the house, they find it difficult to maintain a specific temperature in one zone, as the heat travels upwards. Simon and Melissa make very few adjustments to the heating system, in general, and then mostly during the seasonal shift from summer to winter. If adjustments have to be made during the day, the normal way of doing so is to open the door in order to cool the house down. Again, Simon and

Melissa's competencies are linked more closely to their embodied experiences than ICT competencies (i.e., scheduling a temperature drop). Simon and Melissa like a cold bedroom and a warm bathroom. They like the living room at a constant temperature that allows them to sit in it in a shirt or t-shirt without feeling cold. This setting is also a new norm for Simon: "*So, if I really felt pressured and wanted to save, which I should do, then we should turn down the space heating and put on a sweater. I am well aware of that*."

With age, space heating has thus become a luxury to Simon:

> "*So, there is no doubt that if you really think you want to save on space-heating, then it is just turning down a degree on the radiator. There is no doubt about that. That's luxury. Luxury is perhaps a very good word to describe it . . . It's a luxury not to think about it*."

The new notions of comfort in their new home also make clear the differences between the couple:

> "*So, you are far more cold-skinned than I am (addressed to Melissa). I have a much 'better heater' . . . Melissa is in that age where you run on zero and one. I tease her, saying she has a Ukrainian heating system. It is zero or one—nothing else exists. I have a Danfoss system that you can adjust with a thermostat*."

When asked about how they negotiate concerning which temperature to set, Simon says that it is Melissa's notion of comfort that determinates the outcome: "*But it is Melissa's comfort level that determines it. I just take off my sweater and socks.*"

Simon and Melissa receive feedback on their energy consumption every morning, as the district heating utility sends them a report containing consumption patterns. Simon is generally interested in these reports and has noticed that they pay extra because their return temperature (determining the tariff) is too high. Therefore, Simon is eager to have the utility visit his house in order to explain to him how he can reduce the return temperature. Simon considers himself to be a bit of an expert on space heating systems but mentions that in this house, the space heating system has become too technical, making it difficult for him to adjust it. He thinks that modern space heating systems require that occupants receive some kind of education so that they can operate them properly. While Simon wants to engage more with his current space heating system, he finds it difficult and is thus eager to get help from professional intermediaries.

However, Simon does not think about space heating consumption very much anymore:

> "*So, something like energy, I'm really interested in that. I also work in a business that works with the energy sector . . . So, something like energy consumption, that interests me. But I have to say that the behaviour I have developed here, as space heating doesn't affect you, means that you don't think about it. I don't go around adjusting in order to make savings anymore. I don't do that.*"

While Simon feels that the new smart system has increased his comfort, he is quite unsure about how to operate it. He has tried to tinker with the system a bit, examined the IHD and looked through the manuals, but he has restrained himself from engaging with the system too much, as he did not know what consequences his actions would have:

> "*I think that my previous approach has taught me that there is probably a reason why people write manuals on how to operate it. After all, I have myself been involved in doing so for many years. There is always an idea behind people sitting down and writing things. After all, it is for people to sit down and read them. But when I was younger, I just wanted to press all the bottoms. I know better now. Maybe I can also acquire the knowledge it requires in another way.*"

The feedback from the utility has kept Simon interested in the smart system. The feedback reminds him that space heating practices are meaningful to him and that he should calibrate the system, allowing him to do some good for the climate, which worries him. However, the trend in increasing levels of automation is not what Simon prefers. Instead, he would prefer to receive more personalized feedback:

> *"There is insanely much laziness in this. There really is a lot of laziness. I think the laziness lies in the fact that it (energy consumption) is not visible enough . . . Let's imagine we have a screen sitting here (he points to the front door) and then in the corner it could show your energy consumption. In that way, it would be very, very visible."*

However, Simon is unsure as to whether having such a screen is a good idea. Though he does not like to be under surveillance, he thinks it is a good idea:

> *"I think my motivation is that I want to be a good citizen and have green consumption. I can only speak for myself, but I want such a Chinese attitude there, a surveillance society where the Chinese give you points according to how good a citizen you are. [Simon laughs]. I fit well in such a system. That's the engineer in me. I would try to get as many points as possible. Society controls your behaviour. But of course, there is someone that this would have the opposite effect on, who would do everything they could to counteract it because they wouldn't like to be monitored. But I'm probably the type that would feel motivated by it."*

Previously Simon had been quite opposed to surveillance, but now he is okay with the utility knowing about his consumption. Future systems should provide an opportunity to override them and disconnect from the smart grid, according to Simon.

6. Reconfiguring Competencies for Space Heating Practices

The four vignettes outlined above showcase the very different ways in which space heating practices are performed and reproduced. When occupants are confronted with new technology for controlling their space heating, the vignettes highlight the very different ways in which they reconfigure their space heating practices, including making more or fewer adjustments during the day to maintain comfort. At the same time, the vignettes also display the practices as an entity i.e., the collective structures of conducting space heating. When a new heating technology, such as a smart home heating technology, is introduced and implemented in households, existing space heating practices will therefore be reconfigured—having an impact on both what occupants perceive of as meaningful practices and how they perform such (i.e., what competencies they use). In the following sections, the elements of the competencies will be discussed. This discussion will include a discussion of how practice reconfigurations vary across specific sets of competencies e.g., those who have more experience with ICT equipment. At the same time, it will show how previous ways of performing space heating practices are embodied in occupants, and that practices rely on a complex nexus of previous exposures to, and experiences with, space heating and ICT. Knowledge of the very different ways in which competencies are reconfigured in space heating practice is crucial for the success of demand-side-management initiatives such as smart home technologies. As the results show, the adoption of, and adaption to, these technologies is not straightforward, and we cannot expect that occupants will accept a change in their space heating practices and become more flexible. The results thereby raise a critique of the current representation of smart home technologies aimed at enabling energy flexibility, as they are too limited in scope and their understanding of everyday life. While the four vignettes above are the focus in this article, the discussion and reconfiguration of space heating practices are based on a total of 16 interviews. The ethnographic vignettes highlighted in this analysis have been used to provide detailed accounts of the very complex ways in which social practices are reconfigured. As seen in Figure 2, the four different types identified and illustrated by the ethnographic vignettes, represent different approaches of respectively having more or less ICT competences, and engaging more or less with the smart home technologies related to space heating. The discussion below is thus the outcome of a qualitative analysis of the entire research data of all 16 households.

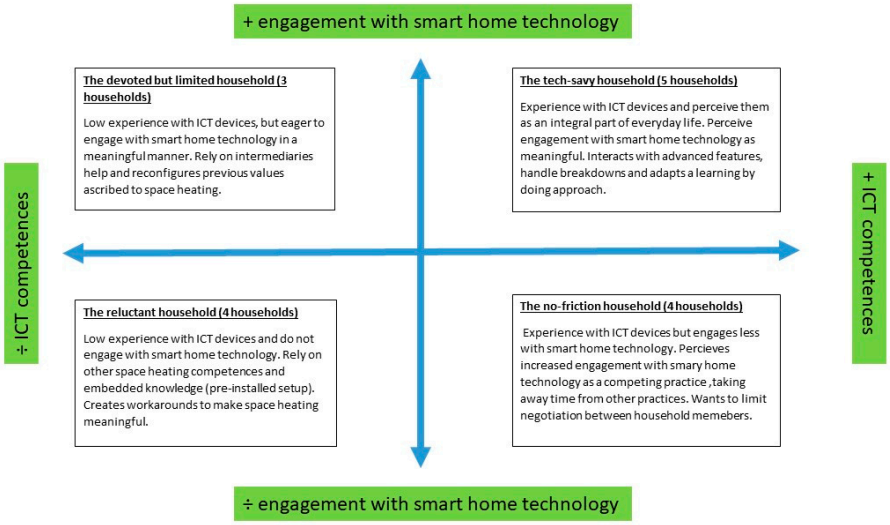

Figure 2. Four variations of space heating (re)configuration.

6.1. The Tech-Savvy Household

The tech-savvy household is represented in the interview with Carina but similar reconfigurations of space heating practices are seen in five other households (IDs: 1, 2, 3, 5 and 8). Occupants like Carina may express and show familiarity and trust in connected devices and operate them confidently. They are used to having ICT devices integrated into everyday life and use these devices in many different aspects of everyday life. A distinction in their space heating practices is that they engage more (compared to the other informants) with the smart home technology. They may operate it on a weekly or even daily basis and adjust the scheduling if routines in everyday life change with the advent of holidays, weekends as so on, much as Carina does. This control is most likely wielded from their preferred device, which is the smart phone, as we saw with Carina. Their phones are also used to set up the more advanced features and conduct longer-term planning. The IHD is used on an ad-hoc basis and engagement takes place only when occupants leave the home for e.g., shopping, for which they set the system on pause. As seen especially in the case of Christian, who lives with Carina, they like to tinker with the technology and are not afraid of making adjustments along the way, as accessing the technology comes easily to them. These occupants are thus likely to be very good at adjusting their new devices to everyday life, which could potentially mean that they would also be better at enabling energy flexibility. Their methods for learning about the system and handling breakdowns are also likely to be different from those of others. Their learning curves may not be as steep as those of others, as they often learning by doing. If breakdowns do happen, such as when the phone app fails or the Wi-Fi connection is interrupted, they will be very quick in handling the situation themselves, and they will rarely or never call for assistance, as we saw with Carina and Christian. In fact, many of the occupants did not know whom to contact should breakdowns occur. These occupants also have a higher level of trust in the technology and have no problems with exchanging data and information on their consumption with the utility. Those with ICT-related competencies seem more likely to engage more frequently with their smart home devices, and the selected case shows how they continue to perform space heating practices which are meaningful to them and are, to a large degree, in accordance with the knowledge embedded in the technology.

6.2. The 'No-Friction' Household

The 'no-friction' household is represented in the interview with Noah but is also represented by three other households in the data (IDs: 16, 10 and 7). Overall, occupants in these households express a relatively high level of experience with connected technologies and use ICT devices in many spheres of everyday life. However, their engagement with the smart home technology for

controlling space heating is likely to be rather low. Occupants in these households express that they want space heating to be as convenient as possible, meaning that it should not cause friction in everyday life. The informants describe their everyday lives as structured and routinized, and, while they express interest in the technological capabilities of smart home technology, it is important for them that it does not take time away from other practices. Hence, they are more likely to engage less with the smart home technology and create workarounds (e.g., increasing the use of airing for lowering the temperature). These occupants are more likely to set their comfort standards higher than they normally would in order to prevent as many negotiations (between household members) on space heating practices as possible. However, the 'no-friction' households are positive towards the increased digitalization and automation of space heating practices, and they indicate that a 'dream scenario' would be to have increased automation and intelligent AI features able adopt to their needs, thus allowing limited engagement with the technology. While occupants in these households seem to carry the competencies for engaging with smart home technology (which are also embedded in the technology itself), the data show how practices are dynamic and reconfigure in very different ways. To these informants, having the necessary competencies is not directly linked to increased engagement with the technology. Instead, the meanings and norms that occupants ascribe to their performances are just as important. To them, meaningful space heating practices are convenient and do not take away time from other practices in everyday life. Despite possessing the competencies for engaging with ICT equipment, they regard the integration of smart home technology in their homes as something which increases negotiations between household members and takes away time from other (and more important) practices.

6.3. The Reluctant Household

The reluctant household is represented in the narrative of Charlotte and Mia and describes four other households (IDs: 11, 12, 13 and 15). Occupants in these household are likely to express little experience with ICT devices; in general, they prefer to perform everyday practices without using such devices. At the same time, they tend to express a low level of engagement with the smart home technology for controlling space heating, and they find the technology rather complex and challenging. When they do engage with the technology, they seldom or never make use of the more 'advanced' features, such as scheduling. Instead, they seem to prefer to operate the thermostats and adjust every room individually. Their preferred platform for controlling heating, aside from the thermostat, is the IHD, with which they try to engage but at times find difficult to understand. Their methods for learning how to use the technology are also quite different compared with other occupants. They rely heavily on the preinstalled features embedded in the system and also highlight that intermediaries, such as installers or utility professionals, have become increasingly important, as they see them as key personnel for understanding how to use the technology and when breakdowns occur. The occupants do not generally like to tinker with the system, as they do not feel confident in their abilities to control the system and are afraid of 'ruining something'. The reluctant household perceives that being involved in controlling their own heating system could potentially be risky, which highlights the complexities of smart home systems and how they are used and perceived. Instead of adjusting the system to everyday life, these occupants are quick to create workarounds when their space heating practices become increasingly complex. Such workarounds often include using items they "trust", such as clothes or blankets. Coping with everyday life and generating the same care and comfort levels wherever they are is important for these occupants, and dealing with the new smart home technology often results in instances in which the occupants will disregard the technology completely and turn to the familiar. They experience increasing levels of complexity due to their dependence on the smart home technology, and, at times, they feel a loss of control. In order to regain control, they become more and more reluctant to use the system. The vignette of Charlotte and Mia, as well as the data from the four other households in this 'group', shows that competencies matter when occupants are confronted with new technology for controlling space heating. Furthermore, the data show the importance of

other (embodied) competencies, which the occupants in these cases bring into play in order to perform their space heating practices in a meaningful manner. While these occupants might find it meaningful to engage with their space heating, lacking competencies for these new devices is problematic.

6.4. The Devoted but Limited Household

The devoted household is represented in the narrative of Simon and is showcased by three other households as well (IDs: 4, 6 and 14). These occupants tend to state that they lack the technological know-how needed for engaging with smart home technology. Nonetheless, in contrast with the 'reluctant' households, these households are eager to engage regardless, and the tactics which they apply do not necessarily include abandoning the technology as a whole. Instead they are likely to try to adapt their everyday lives to the technology. Due to their lack of experience, they find it quite difficult to engage with smart home technologies and seldom make use of the more advanced features. They prefer receiving feedback from the utility on how to operate their systems effectively. In general, they rely more heavily on intermediaries and want them to install and set up their systems.

As the devoted household is eager to engage with the smart home technology but does not possess the necessary knowledge, they tend to reconfigure their space heating practices in other ways. These reconfigurations are characterized by changes in the meanings and norms that they attribute to their space heating practices. For instance, a change in values could decrease the importance of energy savings while increasing the importance of comfort. For these occupants, being in control and being caretakers is important and when their competencies for controlling space heating change, they tend to reconfigure the meaning they attribute to space heating practices.

Table 3 illustrates the dynamics of space heating practices and how they reconfigure. While all the interviewed households have smart home technology in their home, it varies to what degree they use it but also which part of it they use, and if they bring other equipment into play (and for what purposes). Some occupants therefore rely solely on smart home equipment (and all its features), while others bring materiality into play, which they 'trust' in order to still being able to perform space heating in a meaningful manner. Furthermore, our analysis show that ICT competencies does not necessarily translate into increased engagement with smart home technology. Which values and meanings that occupants find meaningful also influences their space heating practices. This again highlight the interconnectedness of different elements in practices and the need for understanding reconfiguration of practices as something which is in a constant flux.

The above presentation of different 'household-types' and how they engage with smart home technology is not intended as any general classifications which any household will fit into. Instead, the aim is to show how heating and ICT competencies vary among occupants in smart homes and that the configuration of new heating practices will depend these competencies. How occupants use and understand smart home technology depends on previous experiences and ways of performing space heating, as well as experiences with ITC from performing other practices.

Taking a practice theoretical perspective in our analysis, we interpret practices as collective entities across time and space, carried and performed by practitioners. What we have pointed out and analysed is the variation in the performance of these collective practices. A better understanding of how variations in competencies related to both ICT and heating practices takes part in shaping individual performances of new space heating practices will also help us understand how the collectivity of these reconfigured practices related to heating home evolves.

The analysis also highlight the dynamics of practices and how reconfiguration is in constant flux. Hence, competencies are not all that matter in the reconfiguration of (new) heating practices. Heating practices are closely linked to the meanings and norms that occupants carry (e.g., the 'no-friction' household) as well as the materiality in place. Furthermore, practices come in bundles, and space heating is related to other practices in everyday life e.g., cooking, playing computer games. Thus, in order to understand the reconfiguration of heating practices, it is important to understand everyday life.

Table 3. Different ways of engaging with smart home technology for space heating.

Different Ways of Engaging with Smart Home Technology	Elements of Space Heating Practices		
	Materiality	**Meanings**	**Competencies**
	(Objects, Tools, Infrastructures) [25]	**(Cultural Conventions, Expectations and Socially Shared Meanings) [25]**	**(Knowledge and Embodied Skills) [25]**
The tech-savvy household	Smart phone (multiple family members use the app) IHD (in-home-display) Blankets (To provide comfort) Clothes (To provide comfort)	Smart = convenient and comfortable Variety and choice Fine-grained control ICT equipment as integral part of everyday life	Technological ICT tinkering ICT competencies
The 'no-friction' household	Smart phone (limited to one phone) IHD Blankets (used to create workarounds) Clothes (used to create workarounds)	Care and health Providing comfort Limit negotiations Delegating control User friendly	Limiting technological interaction ICT competencies
The reluctant household	Thermostats Blankets (used to create workarounds) Clothes (used to create workarounds)	Smart technologies as unnecessary (a gadget) ICT increases complexity Maintain control	Avoiding third-party control Regulates on thermostats Creating workarounds
The devoted but limited household	IHD Thermostats Blankets (To provide comfort) Clothes (To provide comfort) Feedback monitors	Understanding and mastering the heating system Providing economic savings and comfort by themselves	Competencies on 'older' space heating technologies Competencies on energy infrastructure (e.g., return temperature, meter readings, calibrating heating systems)

7. Discussion and Conclusions

As the analysis suggests, some households exhibit greater ease in performing space heating practices using smart home technology. However, this framework should be used with caution. Even though some occupants might be more competent or have greater ease in controlling the technology and the embedded knowledge, it cannot be concluded they are more competent at enabling energy flexibility. Instead the purpose of this study is to show the different ways in which space heating practices are being performed by occupants, as they draw on embodied knowledge in a routinely manner, and that new space heating practices therefore reconfigure in very different ways. Therefore, challenges remain in terms of the adoption of smart home technology, as with every material arrangement, as it is not possible to foresee how occupants will actually engage on an individual level. Hence, it is necessary to take broader and more holistic perspectives on everyday life and understand why occupants consume energy (or heat their homes) in the way that they do. The limited scope of the flexibility scenario, which only highlights the technical possibilities for enabling flexibility, is not enough, and, as previous research has shown, smart home technology implies a number of collective structures, such as increased notions of convenience and comfort [27,35]. Interventions aimed at enabling flexibility must consider the fact that most occupants do not consider energy to be a commodity in and of itself.

Scenarios of energy flexibility should to be translated into something meaningful for occupants in their everyday lives, taking into consideration the fact that they come with different competencies and that the way in which they approach new technologies will be very dependent on such ways of doing.

Focusing on competencies, the above analysis suggests that occupants perform space heating practices very differently and according to their own set of competencies. Such competencies are habitual and embodied throughout life, and occupants draw on these in a routinely manner in everyday life. Competences are though not static and with the integration of smart home technology in the domestic sphere, space heating practices change. Both the provision of space heating and the competencies needed for operating the heating system change. Hence, some occupants are better equipped than others, as they have had previous experience with ICT and other internet-connected devices, allowing them to better understand and engage with this new technology and avoid finding

everyday life increasingly complex. As decision makers around Europe are rolling out smart devices for enabling energy flexibility, aspects of everyday life need to be included in the 'equation', as this analysis shows. No matter how 'smart' the devices become, it is important that they be adaptable to everyday life, that occupants find them meaningful and that occupants possess the necessary competencies for controlling them. Otherwise, occupants will quickly become reluctant to use them or create workarounds in order to make their everyday lives less complex or to achieve contrary goals.

The roll-out of smart home technology in our homes is already in process and large manufacturers of electronic devices have already commercialized smart home products, and, with the integration of households into the smart grid, utilities and policy makers are looking at utilizing this increased digitalization and automation, for e.g., enabling energy savings and flexibility. In this process of implementation, it is important to realize that the embedded knowledge in the smart home technology is not always understood and used as designed. Policy makers must consider how knowledge can be abstracted from the technology and how re-enactment of space heating practices using smart home technology can embody some of the knowledge embedded in the technology. Future research agendas should also consider this facet of smart technology.

Author Contributions: Conceptualization, S.P.A.K.L. and K.G.-H.; Data curation, S.P.A.K.L.; Formal analysis, S.P.A.K.L.; Funding acquisition, K.G.-H.; Investigation, S.P.A.K.L. and K.G.-H.; Methodology, S.P.A.K.L. and K.G.-H.; Writing–original draft, S.P.A.K.L.; Writing–review & editing, S.P.A.K.L. and K.G.-H.; Supervision, K.G.-H. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: The authors are very grateful for the time and knowledge which the informants so unselfishly donated to this project. The authors would also express thanks to all the colleagues who lent their support throughout the fieldwork, analysis and writing of this paper. This work was financed by the InterHUB project which is funded by Aalborg University' strategic funding for interdisciplinary research, InterHUB: Intermittent energy—Integrating Households, Utilities, and Buildings. For more information on the project, see: interHUB.aau.dk.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Energistyrelsen. *Energistatistik 2018*; Energistyrelsen: Copenhagen, Denmark, 2018; ISBN 978-87-93180-46-8www.
2. Friis, F.; Haunstrup Christensen, T. The challenge of time shifting energy demand practices: Insights from Denmark. *Energy Res. Soc. Sci.* **2016**, *19*, 124–133. [CrossRef]
3. Nyborg, S. Pilot users and their families: Inventing flexible practices in the smart grid. *Sci. Technol. Stud.* **2015**, *28*, 54–80.
4. Andersen, P.V.K.; Georg, S.; Gram-Hanssen, K.; Heiselberg, P.K.; Horsbøl, A.; Johansen, K.; Johra, H.; Marszal-Pomianowska, A.; Møller, E.S. Using residential buildings to manage flexibility in the district heating network: Perspectives and future visions from sector professionals. *IOP Conf. Ser. Earth Environ. Sci.* **2019**, *352*, 012032. [CrossRef]
5. Johra, H.; Heiselberg, P.; Dréau, J.L. Influence of envelope, structural thermal mass and indoor content on the building heating energy flexibility. *Energy Build.* **2019**, *183*, 325–339. [CrossRef]
6. Le Dréau, J.; Heiselberg, P. Energy flexibility of residential buildings using short term heat storage in the thermal mass. *Energy* **2016**, *111*, 991–1002. [CrossRef]
7. European Parliament. *Council of the European Union Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 Amending Directive 2010/31/EU on the Energy Performance of Buildings and Directive 2012/27/EU on Energy Efficiency*; European Parliament: Brussels, Belgium, 2018.
8. Darby, S. The effectiveness of feedback on energy consumption-A review for DEFRA of the literature on metering, billing and direct displays. *Environ. Chang. Inst.* **2006**, *486*, 26.
9. Hazas, M.; Strengers, Y. Promoting smart homes. In *Energy Fables-Challenging Ideas in the Energy Sector*, 1st ed.; Rinkinen, J., Shove, E., Torriti, J., Eds.; Routledge: London, UK, 2019; pp. 78–87.

10. Goulden, M.; Spence, A.; Wardman, J.; Leygue, C. Differentiating 'the user' in DSR: Developing demand side response in advanced economies. *Energy Policy* **2018**, *122*, 176–185. [CrossRef]
11. Larsen, S.P.A.K.; Gram-Hanssen, K.; Marszal-Pomianowska, A. *Smart Home Technology Enabling Flexible Heating Demand: Implications of Everyday Life and Social Practices, ECEEE 2019 Summer Study on Energy Efficiency: Is Efficient Sufficient?* European Council for an Energy Efficient Economy: Hyéres, France, 2019; pp. 865–873.
12. Hansen, A.R.; Gram-Hanssen, K.; Knudsen, H.N. How building design and technologies influence heat-related habits. *Build. Res. Inf.* **2018**, *46*, 83. [CrossRef]
13. Rinkinen, J.; Jalas, M. Moving home: Houses, new occupants and the formation of heating practices. *Build. Res. Inf.* **2017**, *45*, 293–302. [CrossRef]
14. Gram-Hanssen, K. Residential heat comfort practices: Understanding users. *Build. Res. Inf.* **2010**, *38*, 175–186. [CrossRef]
15. Jalas, M.; Rinkinen, J. Stacking wood and staying warm: Time, temporality and housework around domestic heating systems. *J. Consum. Cult.* **2016**, *16*, 43–60. [CrossRef]
16. Royston, S. Dragon-breath and snow-melt: Know-how, experience and heat flows in the home. *Energy Res. Soc. Sci.* **2014**, *2*, 148–158. [CrossRef]
17. Madsen, L.V.; Gram-Hanssen, K. Understanding comfort and senses in social practice theory: Insights from a Danish field study. *Energy Res. Soc. Sci.* **2017**, *29*, 86–94. [CrossRef]
18. Reckwitz, A. Toward a theory of social practices. *Eur. J. Soc. Theory* **2002**, *5*, 243–263. [CrossRef]
19. Shove, E.; Pantzar, M. Consumers, producers and practices: Understanding the invention and reinvention of Nordic walking. *J. Consum. Cult.* **2005**, *5*, 43–64. [CrossRef]
20. Warde, A. Consumption and theories of practice. *J. Consum. Cult.* **2005**, *5*, 131–153. [CrossRef]
21. Schatzki, T.R. *Social Practices: A Wittgensteinian Approach to Human Activity and the Social*; Cambridge University Press: Cambridge, UK, 1996.
22. Gram-Hanssen, K. Understanding change and continuity in residential energy consumption. *J. Consum. Cult.* **2011**, *11*, 61–78. [CrossRef]
23. Schatzki, T.R. *The Site of the Social: A Philosophical Account of the Constitution of Social Life and Change*; Pennsylvania State University Press: University Park, PA, USA, 2002.
24. Hansen, A.R. 'Sticky' energy practices: The impact of childhood and early adulthood experience on later energy consumption practices. *Energy Res. Soc. Sci.* **2018**, *46*, 125–139. [CrossRef]
25. Shove, E.; Pantzar, M.; Watson, M. *The Dynamics of Social Practice: Everyday Life and How it Changes*; SAGE: London, UK, 2012.
26. Nicholls, L.; Strengers, Y. Peak demand and the 'family peak' period in Australia: Understanding practice (in)flexibility in households with children. *Energy Res. Soc. Sci.* **2015**, *9*, 116–124. [CrossRef]
27. Strengers, Y. *Smart Energy Technologies in Everyday Life: Smart Utopia?* Palgrave Macmillan: Basingstoke, London, UK, 2013.
28. Hargreaves, T.; Nye, M.; Burgess, J. Keeping energy visible? Exploring how householders interact with feedback from smart energy monitors in the longer term. *Energy Policy* **2013**, *52*, 126–134. [CrossRef]
29. Hargreaves, T.; Wilson, C.; Hauxwell-Baldwin, R. Learning to live in a smart home. *Build. Res. Inf.* **2018**, *46*, 127. [CrossRef]
30. Hanmer, C.; Shipworth, M.; Shipworth, D.; Carter, E. How household thermal routines shape UK home heating demand patterns. *Energy Effic.* **2019**, *12*, 5–17. [CrossRef]
31. Blue, S.; Shove, E.; Forman, P. Conceptualising flexibility: Challenging representations of time and society in the energy sector. *Time Soc.* **2020**. [CrossRef]
32. Shove, E.; Walker, G. What is energy for? Social practice and energy demand. *Theory Cult. Soc.* **2014**, *31*, 41–58. [CrossRef]
33. Vannini, P.; Taggart, J. Onerous consumption: The alternative hedonism of off-grid domestic water use. *J. Consum. Cult.* **2016**, *16*, 80–100. [CrossRef]

34. Day, R.; Hitchings, R. 'Only old ladies would do that': Age stigma and older people's strategies for dealing with winter cold. *Health Place* **2011**, *17*, 885. [CrossRef]
35. Strengers, Y.; Nicholls, L. Convenience and energy consumption in the smart home of the future: Industry visions from Australia and beyond. *Energy Res. Soc. Sci.* **2017**, *32*, 86–93. [CrossRef]